CLIMATE CENTRAL SOLUTIONS BRIEF: BATTERY ENERGY STORAGE

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Research brief by
Climate Central

CLIMATE CENTRAL

Climate Central Solutions Brief: Battery Energy Storage

Batteries are having a moment.

SUMMARY

In early October, the Royal Swedish Academy of Sciences awarded the 2019 Nobel Prize in Chemistry to three scientists for their research on lithium-ion batteries. Their work decades ago led to batteries becoming smaller, more powerful, more portable, and rechargeable, all of which have transformed our laptops, our phones, and our lives.

The same month, news headlines lauded batteries' ability to act as backup generators during grid outages, as millions endured planned blackouts during this year's fire season in California.

Batteries are also being touted as the "Holy Grail" for reducing greenhouse gas emissions as we electrify our vehicles and seek to convert our energy grid to a carbon-free system. When connected to a renewable energy source, such as photovoltaic solar panels, batteries can take in the clean energy produced when the skies are clear and sunny, store it, and then send it back to the electricity grid at night, on cloudy days, or whenever needed. And batteries can potentially reduce electricity bills for customers who use them to send power back to the grid when demand is at its peak and energy prices are at their highest.

Also, rechargeable batteries are powering the rise in plug-in electric vehicles. In 2018, more than 360,000 electric vehicles were sold in the United States, an increase of 81% over 2017. With transportation contributing 29% of U.S. carbon emissions, electric vehicles have the potential to significantly lower those emissions, provided the electricity grid that supports them is powered by low-carbon energy.

Just as the cost of energy derived from wind turbines and photovoltaics has dropped in recent years, the price of battery energy storage is declining as well. But there are still regulatory hurdles, safety issues, and other challenges before battery energy storage can become a major component of the electricity grid in the United States. This Climate Central Solutions Brief provides an overview of batteries, including the science, their potential applications, and the market and policy forces shaping the current status and future of batteries.

SECOND LIFE FOR ELECTRIC VEHICLE BATTERIES

When electric vehicle (EV) batteries are no longer able to meet the high standard performance thresholds for transportation, they can still be reconditioned to store energy for the stationary grid for another 10 years. The National Renewable Energy Laboratory is exploring this reuse to help increase EV ownership and reduce the cost of grid-connected energy storage systems.

THE SCIENCE BEHIND BATTERIES

Lithium-ion batteries currently have the highest energy and power densities among alternative battery chemistries, which is why they're in all of our cell phones and other portable devices. They can store a large amount of energy and deliver it quickly.

Lithium-ion batteries store energy in the form of chemical energy, and have three main parts: the anode (negative electrode), the cathode (positive electrode), and the electrolyte, a chemical medium separating the two electrodes. Chemical reactions at the anode release electrons that travel through an external circuit (to power your laptop or your electric vehicle or something as complex as the Mars Curiosity rover) and back to the cathode where they recombine with the positive ions that traveled through the electrolyte. The process also works in reverse when a stream of electrons (electricity) from an external source is fed to the battery circuit. This is how batteries are recharged.

Despite their advantages, lithium-ion batteries' components are inherently volatile. Remember the hoverboards that caught fire a few years back? An explosion can result when the thin separator that keeps the elements of the battery apart weakens or disintegrates and the battery overheats. Even small lithium batteries can store large amounts of energy, and e-cigarettes, cell phones, and hoverboards have been known to explode. Still, for all their widespread use, instances of catching fire are still relatively uncommon and technology advances in lithium-ion batteries continue, including efforts to make them safer.

In addition, lithium mining has potentially negative environmental effects. With more electric vehicles being produced, lithium consumption has correspondingly increased, and many researchers are studying the environmental sustainability of lithium extraction. Lithium is found in the brine beneath salt flats; to extract it, holes are drilled to pump the brine to the surface. The process can divert great amounts of clean water away from communities and agriculture. Further, recycling infrastructure has not yet been developed for lithium-ion batteries, and they can be toxic or flammable when disposed of in landfills.

Lithium-ion batteries represent only one type of energy storage. Several other types of batteries can be developed for different applications.

MICROGRID PILOT IN BORREGO SPRINGS, CALIF.

The 2,800 people who reside in Borrego Springs, nearly 90 miles northeast of San Diego, are served by a 60-mile transmission line subject to wildfires, windstorms, flooding, and extreme temperatures. After a 2007 wildfire took out the transmission line, San Diego Gas & Electric piloted the nation's first renewables-plus-storage microgrid in the town, which incorporates diesel generators, solar power, batteries, and control systems.

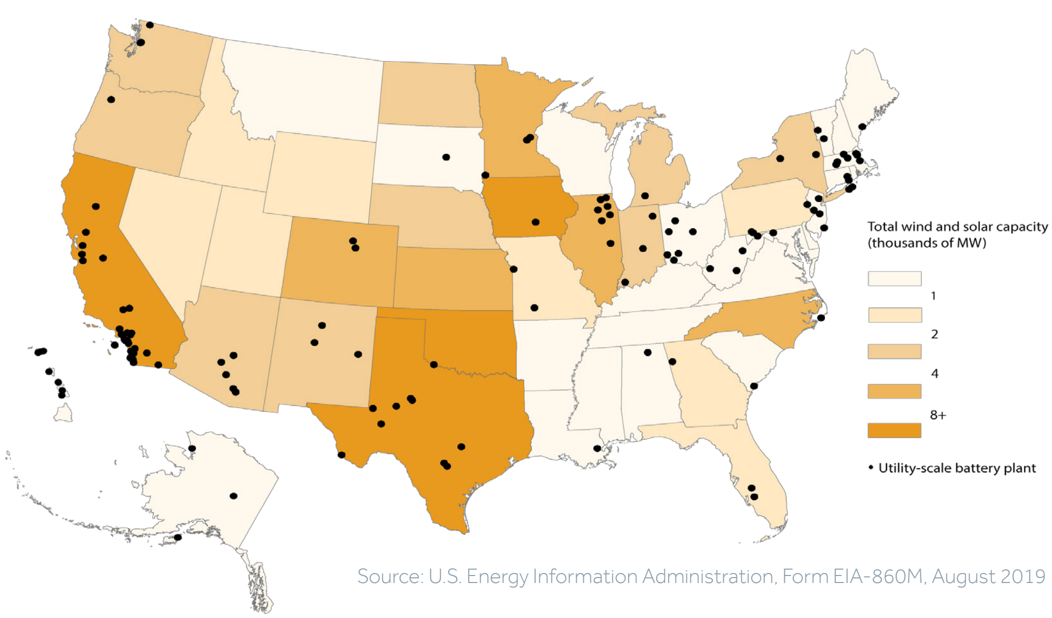
BATTERIES AND RESILIENCE

Historically, some residents and business owners have kept their lights on during storms or blackouts with gas or diesel generators, which tend to be noisy and polluting. Distributed energy resources—small-scale power generation from sources like rooftop solar panels or battery storage—can increase resilience, particularly as climate change brings more extreme weather events and greater potential for loss of power. As this power is produced by a residence or business, it is referred to as "behind the meter" and is controlled by the customer producing it, and backed up by the grid.

The vast majority of homeowners or businesses that produce their own power through solar will still find themselves without power during a grid outage. To truly be independent of the electrical grid, solar panels generally must be accompanied by a storage system and an inverter (which converts the electrical output of solar panels into a usable form of electricity) that enables them to become their own freestanding energy system, acting as a microgrid.

But battery storage is expensive, and many in California or other parts of the country who are vulnerable to fires or outages from storms cannot afford to simply purchase a system. Plus, traditional utilities and regulators have long struggled with the growth of

Figure 1. Solar, Wind and Battery Energy
Large-scale installations powering the country



Source: U.S. Energy Information Administration, Form EIA-860M, August 2019 distributed generation, and are still working to figure out policies and rate designs to allow for its increase. These attitudes may be changing in the wake of the fires and outages in California. In September, the California Public Utilities Commission announced changes to their Self-Generation Incentive Program that focuses on wildfire prevention, creating larger subsidies to assist low-income customers and critical service facilities, in addition to focusing on reducing greenhouse gas emissions.

Microgrids can deliver resiliency by allowing a facility to operate during an electrical grid outage. Microgrid systems are already in use by many entities that must have uninterrupted access to electricity, including military installations, industrial facilities, hospitals, wastewater treatment plants, and universities. In the past, microgrids often relied on natural gas and/or diesel generation, but microgrids using renewables increased from about 4 MW in 2008 to 164 MW in 2016, with solar accounting for 73% of this growth. In addition to providing resilience, in some instances microgrid systems reduce energy costs, as the microgrid can sell excess energy back to the grid, especially during peak demand times. In the U.S., microgrids typically coordinate with the larger distribution grids, until a blackout occurs, when the microgrid is able to become its own "island." Microgrids also can eliminate the need to transmit power over long distances, taking the pressure off large power lines and making fire-prone areas safer.

BATTERY TO PROVIDE RESILIENCY FOR ANDERSON COUNTY, S.C.

Duke Energy is installing a 5-MW lithium-ion battery storage system to support the Anderson Civic Center, which operates as an emergency shelter and command center during hurricanes and other crises. The battery capacity allows the center to run for roughly 30 hours without grid power and will also allow Duke Energy to use it for grid stability during periods of peak customer demand.

BATTERIES HELP WITH INTERMITTENCY OF SOLAR AND WIND

As costs of solar and wind energy have plummeted in recent years, their installed capacity has grown dramatically. But the sun doesn't always shine and the wind doesn't always blow, and this can threaten the reliability of the electric grid.

On the nation's current electric grid, energy is typically used as soon it's generated; supply must match demand, or customers will face power surges or blackouts. California now produces so much solar energy in the middle of sunny days that it pays Arizona and other states to take the power off its grid so it doesn't overload its transmission lines. Batteries can store some of this energy making them critical to ensure grid stability and for the wider deployment of renewable energy.

In the U.S., renewable generation has doubled since 2008, providing a record 18% of all electricity generation in the United States in 2018. Most of that increase in renewable energy—nearly 90%—came from wind and solar generation. And more wind and solar is expected to come online, with renewable growth expecting to outdistance fossil fuel growth by June 2022. Figure 1 shows the utility-scale solar and onshore and offshore wind capacity by state as of August of 2019, for installations larger than 1 megawatt.

This growth has been encouraged by adoption of "renewable portfolio standards" in 29 states that require a specified percentage of the state's electricity to come from renewable sources. Eleven states currently have targets of 50% or more by mid-century. For example, California aims to achieve 60% renewable energy by 2030 and 100% zero-carbon electricity by 2045.

Table 1. Utility Scale Capacity in Megawatts, Installations > 1MW as of August 2019

Battery Storage		Wind		Solar	
California	262	Texas	26,407	California	11,203
Illinois	133	Iowa	8,922	North Carolina	4,104
Texas	114	Oklahoma	8,071	Florida	1,976
Hawaii	63	Kansas	6,150	Texas	1,965
West Virginia	50	California	6,080	Nevada	1,833

As renewables have grown, so has battery storage at the utility-scale (one megawatt or greater). Total installed capacity of utility-scale battery storage (one megawatt or greater) has more than quadrupled from 214 MW installed in 2014 to 1,000 MW installed by August 2019. Projections are for an additional 2,500 MW to come online by 2023, according to the U.S. Energy Information Administration. Figure 1 shows installed large-scale battery systems as of August 2019, which most commonly use lithium-ion battery technology.

BATTERIES HELP WITH DEMAND

Battery energy storage can play a critical role during periods of high energy demand—notably, when people get home from work and turn on the lights, appliances, and plug-in electric vehicles, precisely at the time when the sun is setting. The resulting mismatch of supply and demand results in the so-called "duck curve" (see Figure 2).

For years, utilities have used natural gas "peaker plants" that come online quickly when the grid demands more energy. Peakers operate infrequently—only at times of peak demand when they get paid a higher price, relying on these peak periods to cover their costs of operation. But as they're used only for a few hundred hours per year, and with the costs of battery storage declining, analysts see the potential for batteries to serve peak demand instead, offering a carbon-free alternative.

BATTERIES' DECLINING COSTS AND GOVERNMENT POLICY

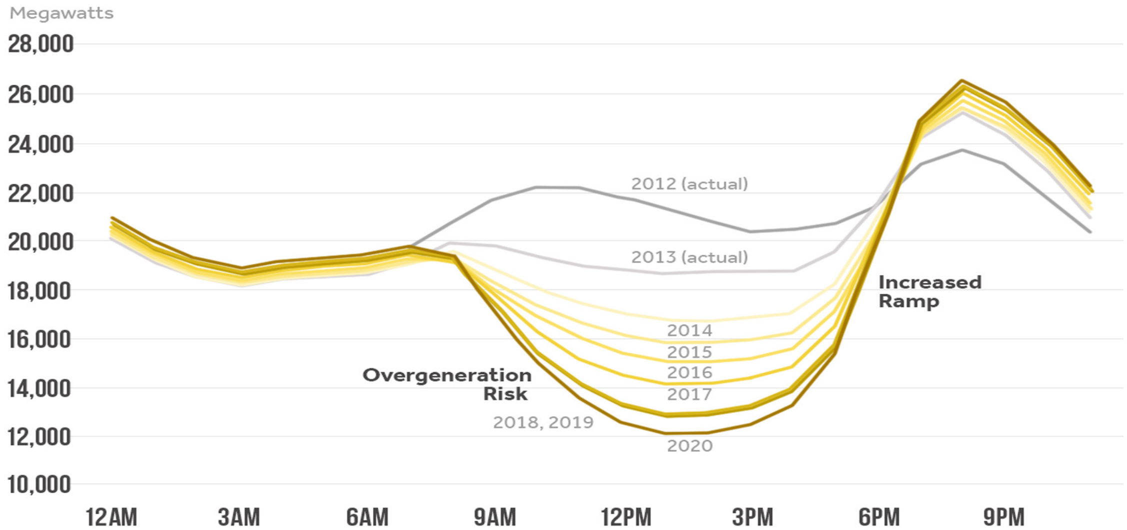
Although its price is declining, battery storage is more expensive than other energy sources, and state and federal government policies, such as procurement goals, financial incentives, or requiring storage capacity in state energy plans, will impact the future growth of battery storage.

Most utility-scale storage systems are overseen by independent, federally regulated organizations charged with controlling the power grid and electricity pricing, called Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs). In February 2018, the Federal Energy Regulatory Commission approved an order requiring these state and regional overseers to lower regulatory barriers to new energy storage technologies, in order for them to compete with other energy generation.

PJM (Pennsylvania-Jersey-Maryland, the RTO for 13 eastern states) has the largest amount of large-scale battery installations, with a storage capacity of nearly 300 MW. California's ISO is the second largest, overseeing batteries with a total storage capacity of 136 MW as of October 2019, but has the most storage expected to come online because of California's mandate to procure 1325 MW by 2020.

Figure 2. Solar Energy "Duck Curve"

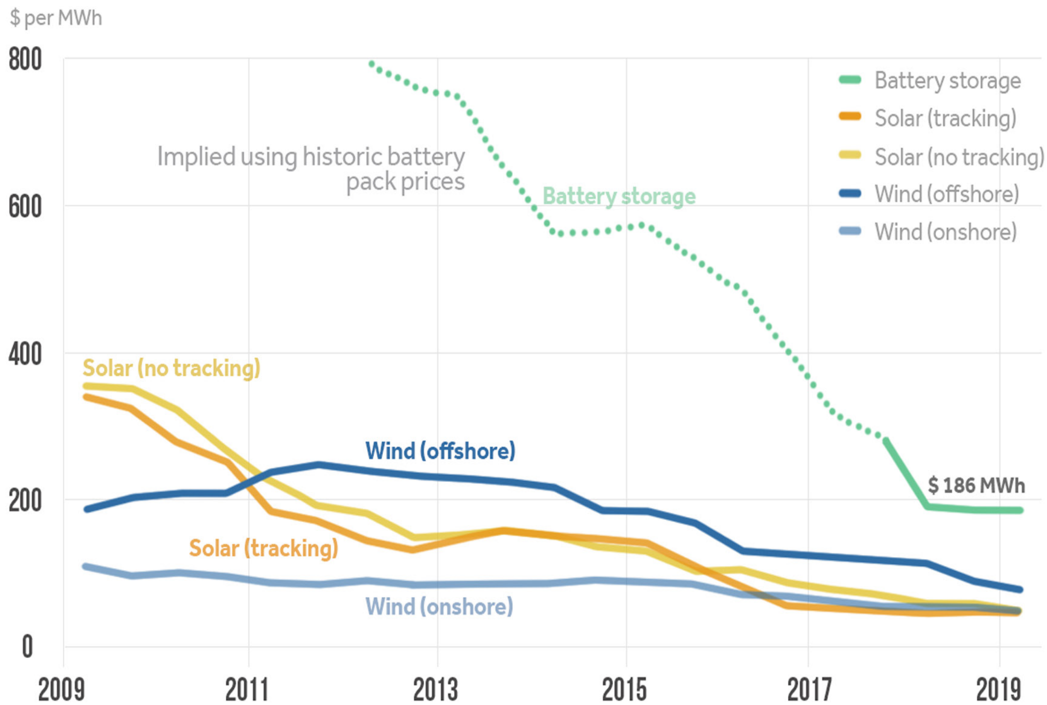
The power grid must balance daily energy supply and demand



Source: CAISO 2013. Duck curve is illustrative and does not quantify actual curtailment, nor does it reflect the impact of mitigation strategies such as battery storage.

Figure 3. Solar, Wind and Battery Prices Falling

BloombergNEF Levelized Cost of Energy 2009-2019



Source: BloombergNEF Note: The global benchmark is a country weighted-average using the latest annual capacity additions. The storage LCOE is reflective of a utilityscale Li-ion battery storage system with four-hour duration running at a daily cycle and includes charging costs assumed to be 60% of wholesale average power price. Data as of October 22, 2019.

Figure 3 shows the recent decline in cost of both lithium storage batteries and renewable energy sources - costs that are projected to continue to fall. Battery storage projects with four-hour duration[1] cost $186/MWh in the second half of 2019, a 35% decrease since the beginning of 2018, and a 76% drop since 2012. Onshore and offshore wind prices have also dropped, about 57% since 2009, and utility scale PV system costs have fallen 86% over the last decade. Large scale battery-plus-solar system prices are becoming more competitive with traditional generation, especially in areas with abundant solar energy output, like the Southwest. With more extreme weather, they may be seen as economically viable—particularly when potential financial losses from grid outages are considered.

THE FUTURE OF BATTERIES

Battery storage technologies are constantly evolving, as scientists and engineers work to find energy storage solutions that are cheaper, safer, denser, lighter, and more powerful. The lithium-ion battery could be replaced by any number of challenger technologies, including aluminum or iron batteries. Electric vehicles are becoming increasingly prevalent, and scientists are predicting longer driving ranges and shorter charging times with innovations in batteries. Even passenger airplanes may one day be powered by batteries powerful enough to meet the demands of liftoff, helping to curb carbon emissions from air travel. Who knows? In another decade or so, more Nobel prizes may be awarded for breakthroughs in battery technology.

NEVADA TO HAVE LARGEST SOLAR COMPLEX IN U.S.

NV Energy, which provides more than 80% of Nevada's electricity, recently announced another 590 megawatts of battery storage paired with three new solar projects totaling 1,200 megawatts.

[1] While energy generation sources (such as natural gas or solar) are described in terms of capacity—the maximum instantaneous amount of power they can emit in units such as megawatts (MW) or kilowatts (kW), Batteries are restricted by how much power they can provide before they need to recharge, known as duration. So a storage system is referred to by both its capacity and its duration. For example, a 50-MW battery with 4 hours of duration would be expressed as being 200 MWh in size. A megawatt hour (MWh) is the amount of electricity produced by a generator operating for one hour.